SUBSTITUTE SPECIFICATION

AN ANALYSIS SYSTEM

This application represents the national stage of PCT/SE03/00081 filed January 20, 2003, which makes a 119(e) priority claim to U.S. provisional application 60/384,118 filed May 31, 2002. Such PCT application additionally makes foreign priority claims to each of Swedish applications 0200147-7 filed January 18, 2002, and 0200215-2 filed January 25, 2002.

Technical Field of the Invention

The present invention relates to an apparatus for analysing the condition of a machine, and to a system for analysing the condition of a machine. The invention also relates to method of operating such a system.

Description of Related Art

Machines with moving parts are subject to wear with the passage of time, which often causes the condition of the machine to deteriorate. Examples of such machines with movable parts are motors, pumps, generators, compressors, lathes and CNC-machines. The movable parts may include a shaft and bearings.

In order to prevent machine failure, such machines should be subject to maintenance, depending on the condition of the machine. Therefore the operating condition of such a machine is preferably evaluated from time to time. The operating condition can be determined by measuring vibrations emanating from a bearing or by measuring temperature on the casing of the machine, which temperatures are dependent on the operating condition of the bearing. Such condition checks of machines with rotating or other moving parts are of great significance for safety and also for the length of the life of such machines. It is known to manually perform such measurements on machines. This ordinarily is done by an operator with the help

of a measuring instrument performing measurements at measuring points on one or several machines.

A number of commercial instruments are available, which rely on the fact that defects in rolling-element bearings generate short pulses, usually called shock pulses. State of the art shock pulse measuring apparatuses may include proprietary technology for generating a value indicative of the condition of a bearing or a machine.

WO 98/01831 discloses a machine having a measuring point and a shaft with a certain shaft diameter, wherein the shaft can rotate when the machine is in use. WO 98/01831 also discloses an apparatus for analysing the condition of a machine having a rotating shaft. The disclosed apparatus has a sensor for producing a measured value indicating the vibration or temperature at the measuring point. The apparatus disclosed in WO 98/01831 has a microprocessor and an analysis routine stored in a memory. According to WO 98/01831 the following process can be performed by running the analysis routine on the microprocessor:

- producing the measured value;
- acquiring interpretation information from an information carrier which is mounted by the measuring point;
- producing an actual condition value, indicating the actual condition of the machine at the measuring point, dependent on the measured value and the interpretation information;
- acquiring a second condition value, indicating the condition of the machine at measuring point at an earlier point of time, from the information carrier;
- producing a relation value dependent on the actual condition value and the second condition value, which relation value indicates a change in the condition.

Summary

An aspect of the invention relates to the problem of achieving a cost-effective improvement of the length of life of machines having a rotating shaft.

This problem is addressed by an apparatus for analysing the condition of a machine, including:

at least one input for receiving measurement data from a sensor for surveying a measuring point of the machine;

data processing means for processing condition data dependent on the measurement data; the data processing means including means for performing a plurality of condition monitoring functions; and

a logger for registering use of at least two of the condition monitoring functions;

wherein

the logger is adapted to register use of a first condition monitoring function a first rate; and

the logger is adapted to register use a second condition monitoring function at a second rate.

This solution can advantageously be used for improving the efficiency of condition monitoring in industry, thereby achieving an increased lifetime of machines having a rotating shaft. It is a human quality to get accustomed to doing things in a habitual manner. This human quality may also be present among machine maintenance personnel, who have become accustomed to monitoring the condition of machines using a favourite method. As technology in the field of condition monitoring advances, however, new condition monitoring functions are introduced, which if they are used, increase the accuracy of the condition monitoring efforts resulting in a longer lifetime of the machines being monitored. Another reason that may cause maintenance personnel to stick with older favourite condition monitoring methods

may be the fact that an advanced condition monitoring apparatus providing unlimited use of novel condition monitoring functions may cost more than the older condition monitoring apparatus. The above solution, however, makes it possible to market an advanced analysis apparatus at a competitive price. Additionally the above solution makes it possible to introduce new condition monitoring functions at a low introduction price, paid at a pay-per-use basis, thereby contributing to a faster acceptance of the new functions. This solution can therefore contribute to improved condition monitoring in industry, thereby achieving an increased lifetime of machines having a rotating shaft. Once a certain condition monitoring function has gained market acceptance, the price for use of that function in relation to other functions may be adjusted or set according to other criteria.

According to an embodiment of the invention there is provided an apparatus for analysing the condition of a machine having a rotating shaft, including:

at least one input for receiving measurement data from a sensor for surveying a measuring point of the machine; the measurement data being dependent on rotation of the shaft;

data processing means for processing condition data dependent on the measurement data; the data processing means including means for performing a plurality of condition monitoring functions;

a logger for registering use of at least one of the condition monitoring functions; and

means for reading a current value of the registered use;

means for comparing the current value with a reference value; wherein

the logger is adapted to register use at a first rate when the current value is above the reference value; and

the logger is adapted to register use at a second rate when the current value is below the reference value.

This advantageously enables a supplier to sell usage at different costs depending on the amount of usage spent by the user. When, according to one embodiment, a user has paid in advance for a certain amount of usage, the reference value is a level indicating that the whole amount of prepaid usage has been spent. This means that any further use will be usage which has not yet been paid for. By the feature of registering such further use at a second rate it is possible to charge a higher cost per unit of usage for such further use.

According to an embodiment the second rate is such that use registered at the second rate causes a higher cost per unit of usage than use registered at the first rate.

According to an embodiment the second rate is such that use registered at the second rate causes a lower cost per unit of usage than use registered at the first rate.

According to an embodiment the registered use is a parameter indicative of a number of executions of at least one of the condition monitoring functions.

According to an embodiment the registered use is a parameter indicative of an extent of time.

According to an embodiment the apparatus inlcudes means for causing a user interface to indicate when use is registered at the first rate.

According to an embodiment the apparatus inlcudes means for causing a user interface to indicate when use is registered at the second rate.

According to an embodiment the logger is adapted to register use of at least two of the condition monitoring functions; and

the logger is adapted to register use of a first condition monitoring function a third rate; and

the logger is adapted to register use a second condition monitoring function at a fourth rate, the fourth rate deviating from the third rate.

According to an embodiment the fourth rate is such that use registered at the fourth rate causes a higher cost per unit of usage than use registered at the third rate.

According to an embodiment the fourth rate is such that use registered at the fourth rate causes a lower cost per unit of usage than use registered at the third rate.

An aspect of the invention relates to the problem of providing equipment for analysing the condition of a machine satisfying the conflicting requirements of reducing the price for a piece of condition monitoring equipment while maintaining profitability for the supplier of the analysis system.

This problem is addressed by an apparatus for analysing the condition of a machine, including an apparatus for analysing the condition of a machine, including:

at least one input for receiving measurement data from a sensor for surveying a measuring point of the machine;

data processing means for processing condition data dependent on the measurement data; the data processing means including means for performing a plurality of condition monitoring functions; and

a logger for registering use of at least one of the condition monitoring functions.

This advantageously enables charging a cost for use of the apparatus.

An embodimnent of the apparatus including:

a communication port; wherein

the apparatus is adapted to be capable of delivering data indicative of the registered use on the communication port.

This advantageously enables delivery of use info to a supplier, for charging a cost. i.e. reporting the amount of use to the supplier.

An embodiment of the apparatus further inlcudes:

means for comparing the registered use with a first reference value,

means for disabling the data processing means or at least one of the condition monitoring functions in response to the outcome of the comparison.

This solution encourages a user to buy additional usage so as to maintain operability of desired functions of the analysis apparatus. Such additional usage may be in the form of a number of measurements using a desired function, or a period of time the duration of which is defined by the registered use and the first reference value.

An embodiment of the apparatus further inlcudes:key reception means adapted to allow further use of the data processing means in response to reception of a first key.

This advantageously enables a supplier to amend the relation between a registered use value and the reference value. Thereby it is possible to increase "the stored amount of use" available before the data processing means is disabled.

An embodiment of the apparatus further inlcudes:

key reception means adapted to allow further use of a selected one of the condition monitoring functions in response to reception of a key associated with the selected function.

This advantageously enables a supplier to amend the relation between the reference value and a registered use value for a selected function. Thereby it is possible to increase "the stored amount of use" available before the selected function is disabled.

An embodiment of the apparatus further inlcudes:

means for reading a current value of the registered use;

means for comparing the current value with a second reference value;

means for registering use at a first rate when the current value is above the second reference value; and

means for registering use at a second rate when the current value is below the second reference value.

This advantageously enables a supplier to sell usage at different costs. When, according to one embodiment, a user has paid for a certain amount A_p of usage, the second reference value is a level indicating that the whole amount A_p of usage has been spent. This means that any further use will be usage which has not yet been paid for. By the feature of registering such further use at a second rate it is possible to charge a higher cost per unit of usage for such further use.

An embodiment of the apparatus wherein:

at least some of the plurality of condition monitoring functions is at least partly embodied by computer program code.

An aspect of the invention relates to the problem of achieving a cost-effective improvement of the length of life of machines with a moving part.

An aspect of the invention relates to the problem of achieving an analysis apparatus for evaluating the condition of a machine,

This problem is addressed by

An apparatus for monitoring the condition of a machine, including:

at least one input for receiving measurement data from a sensor for surveying a measuring point of the machine;

data processing means for processing condition data dependent on the measurement data; the data processing means including means for performing at least two condition monitoring functions;

at least one of the plurality of condition monitoring functions having a locked state and an unlocked state; the locked state prohibiting complete execution of the condition monitoring function; and the unlocked state allowing execution;

means for changing the state of a selected condition monitoring function between the locked state and the unlocked state.

This advantageously provides the analysis apparatus with an improved versatility. A manufacturer can manufacture the apparatus in a single fashion, and a supplier can sell the apparatus in several versions. More precisely, an apparatus having two individually lockable/unlockable functions can be provided in the following versions:

with only the first function unlocked;

with only the second function unlocked;

with the first function and the second function unlocked.

Hence, a supplier can offer the apparatus in three versions, and this allows for selling it at different price levels dependent on the functionality included. Each client is therefore provided with a choice as to which functions to choose.

An embodiment of the apparatus further inlcudes:

key reception means adapted to allow use of a selected one of the condition monitoring functions in response to reception of a key associated with the selected function;

a logger for registering use of at least one of the condition monitoring functions.

means for comparing the registered use with a first reference value,

means for disabling the data processing means or at least one of the condition monitoring functions in response to the outcome of the comparison.

Hence, A manufacturer can manufacture the apparatus in a single fashion, and a supplier can sell the apparatus in more than four versions:

with only the first function unlocked;

with only the second function unlocked;

with the first function and the second function unlocked.

with both functions locked but each function individually or collectively unlockable for a limited amount of use.

Brief Description of the Drawings

For simple understanding of the present invention, it will be described by means of examples and with reference to the accompanying drawings, of which:

Fig. 1 shows a schematic block diagram of an embodiment of a condition analyzing system according to an embodiment of the invention.

Fig. 2 is a schematic block diagram of an embodiment of a part of the condition analyzing system 2 shown in Fig 1.

Figure 3 is a simplified illustration of an embodiment of a memory and its contents.

Figure 4 is a simplified illustration of a second embodiment of the memory and its contents.

Figures 5A and 5B show a flow chart illustrating an embodiment of a procedure according to the invention.

Figure 5C is a simplified illustration of a principle of an embodiment of an account value or amount of usage parameter.

Figure 5D is an illustration of a principle of an embodiment wherein the cost per use changes after a certain level of use has been attained.

Figure 6 is a flow chart illustrating an embodiment of a procedure according to the invention.

Figure 7 is a physical embodiment of an analysis apparatus of the present invention.

Figure 8 is a side view of the apparatus shown in Figure 7.

Figure 9 illustrates the apparatus, shown in Figure 7, being gripped by a hand 140 of a user.

Figure 10 is a top view of an embodiment of the apparatus, illustrating the physical dimensions thereof.

Figure 11 is a side view of the apparatus shown in Figure 10.

Figure 12 is a block diagram of an embodiment of the apparatus shown in Figure 1 and/or Figures 7 and 8.

Figure 13A illustrates a part of memory 60 including a function F_k and an associated status field 142.

Figure 13B illustrates a part of memory 60 according to an embodiment, including a function F_k and an associated status field 142_k.

Figure 14A-14C collectively illustrate a flow chart illustrating an embodiment of a procedure for delivering an apparatus, and for adding use or functionality to the apparatus by means of a key from the supplier.

Figure 15 shows a schematic block diagram of another embodiment of a condition analyzing system 2.

Detailed Description of Embodiments

In the following description similar features in different embodiments may be indicated by the same reference numerals.

Fig. 1 shows a schematic block diagram of an embodiment of a condition analyzing system 2 according to an embodiment of the invention. Reference numeral 4 relates to a client location with a machine 6 having a movable part 8. The movable part may include bearings 7 and a shaft 8 which, when the machine is in operation, rotates. The operating condition of the shaft 8 or of a bearing 7 can be determined in response to vibrations emanating from the shaft and/or bearing when the shaft rotates. Additionally the operating condition of a bearing 7 can be determined in response to temperature measured on the casing of the machine. The client location

4, which may also be referred to as client part or user part, may for example be the premises of a paper mill plant, or some other manufacturing plant having machines with movable parts.

An embodiment of the condition analyzing system 2 is operative when a sensor 10 is firmly attached on or at a measuring point 12 on the body of the machine 6. Although Figure 1 only illustrates two measuring points 12, it to be understood that a location 4 may include any number of measuring points 12. The condition analysis system 2 shown in Figure 1, inlcudes an analysis apparatus 14 for analysing the condition of a machine on the basis of measurement values delivered by the sensor 10.

The analysis apparatus 14 has a communication port 16 for bi-directional data exchange. The communication port 16 is connectable to a communications network 18, e.g. via a data interface19. The communications network 18 may be the world wide internet, also known as the Internet. The communications network 18 may also include a public switched telephone network.

A server computer 20 is connected to the communications network 18. The server 20 may include a database 22, user input/output interfaces 24 and data processing hardware 26, and a communications port 29. The server computer 20 is located on a location 28, which is geographically separate from the client location 4. The server location 28 may be in a first city, such as the Swedish capital Stockholm, and the client location may be in another city, such as Stuttgart, Germany or Detroit in Michigan, USA. Alternatively, the server location 28 may be in a first part of a town and the client location may be in another part of the same town. The server location 28 may also be referred to as supplier part 28, or supplier part location 28. A supplier company who may sell and deliver analysis apparatuses 14 occupies the supplier part location 28. The supplier company may also distribute use allowance to analysis

apparatuses 14 having use restricted condition monitoring functions, as discussed in further detail elsewhere in this document.

According to one embodiment of the system 2 the apparatus 14 is a portable apparatus which may be connected to the communications network 18 from time to time.

According to another embodiment of the system 2 the apparatus 14 is connected to the communications network 18 substantially continuously. Hence, the system 2 according to this embodiment may substantially always be "on line" available for communication with the supplier computer 20.

Fig. 2 is a schematic block diagram of an embodiment of a part of the condition analyzing system 2 shown in Fig 1.The condition analyzing system, as illustrated in Fig. 2, inlcudes a sensor unit 10 for producing a measured value. The measured value may be dependent on movement or, more precisely, dependent on vibrations. Alternatively the measured value may be dependent on temperature.

An embodiment of the condition analyzing system 2 is operative when a device 30 is firmly mounted on or at a measuring point on a machine 6. The device 30 mounted at the measuring point may be referred to as a stud 30. A stud 30 can include a connection coupling 32 to which the sensor unit 10 is removably attachable. The connection coupling 32 can, for example include double start threads for enabling the sensor unit to be mechanically engaged with the stud by means of a ¼ turn rotation.

A measuring point 12 can include a threaded recess in the casing of the machine. A stud 30 may have a protruding part with threads corresponding to those of the recess for enabling the stud to be firmly attached to the measuring point by introduction into the recess like a bolt.

Alternatively, a measuring point can include a threaded recess in the casing of the machine, and the sensor unit 10 may include corresponding threads so that it can be directly introduced into the recess. Alternatively, the measuring point is marked on the casing of the machine only with a painted mark.

The machine 6 exemplified in Fig. 2 may have a rotating shaft with a certain shaft diameter d1. The shaft in the machine 24 may rotate at a certain speed of rotation V1 when the machine 6 is in use.

The sensor unit 10 may be coupled to the apparatus 14 for analysing the condition of a machine. The analysis apparatus 14 inlcudes a sensor interface 40 for receiving a measured signal or measurement data, produced by the sensor 10. The sensor interface 40 is coupled to a data processing means 50 capable of controlling the operation of the analysis apparatus 14 in accordance with program code. The data processing means 50 is also coupled to a memory 60 for storing the program code.

According to an embodiment of the invention the sensor interface 40 inlcudes an input 42 for receiving an analog signal, the input 42 being connected to an analogue-to-digital (A/D) converter 44, the digital output of which is coupled to the to the data processing means 50.

The program memory 60 is preferably a non-volatile memory. The memory 60 may be a read/write memory, i.e. enabling both reading data from the memory and writing new data onto the memory 60. According to an embodiment the program memory 60 is embodied by a FLASH memory. The program memory 60 may include a first memory segment 70 for storing a first set of program code 80 which is executable so as to control the analysis apparatus 14 to perform basic operations (Figure 2 and Figure 3). The program memory may also include a second memory segment 90 for storing a second set of program code 100.

According to some embodiments of the invention the second set of program code is initially disabled so as to prohibit execution of the second set of program code. The disabled data 100 may be enabled in response to reception of a key.

According to an embodiment of the invention the apparatus 14 inlcudes an interface means for receiving the key.

The data processing means 50 is also coupled to a read/write memory 52 for data storage. Moreover, the data processing means 50 may be coupled to an analysis apparatus communications interface 54. The analysis apparatus communications interface 54 provides for bi-directional communication with a measuring point communication interface 56 which is attachable on, at or in the vicinity of the measuring point on the machine.

The measuring point 12 inlcudes a connection coupling 32, a readable and writeable information carrier 58, and a measuring point communication interface 56.

The writeable information carrier 58, and the measuring point communication interface 56 may be provided in a separate device 59 placed in the vicinity of the stud 30, as illustrated in Figure 2. Alternatively the writeable information carrier 58, and the measuring point communication interface 56 may be provided within the stud 30. This is described in more detail in WO 98/01831, the content of which is hereby incorporated by reference.

The sensor unit 10 inlcudes a vibration transducer, the sensor unit being structured to physically engage the connection coupling of the measuring point so that vibrations of the machine at the measuring point are transferred to the vibration transducer.

The analysis apparatus 14 inlcudes an analog-to-digital converter 44 electrically connected to receive an output delivered by the sensor unit 10, a microprocessor 50 electrically connected to receive an output of the analog-to-digital converter, and an analysis apparatus communication interface 54 connected to the microprocessor.

The system 2 is arranged to allow bidirectional communication between the measuring point communication interface 56 and the analysis apparatus communication interface 54. The measuring point communication interface 56 and the analysis apparatus communication interface 54 are preferably constructed to allow wireless communication. According to an embodiment the measuring point communication interface and the analysis apparatus communication interface are constructed to communicate with one another by radio frequency (RF) signals. This embodiment includes an antenna in the measuring point communication interface 56 and another antenna the analysis apparatus communication interface 54.

Embodiments of the measuring point 12 and the communications interfaces 54/56 are described in more detail in WO 98/01831, the content of which is hereby incorporated by reference.

Figure 3 is a simplified illustration of an embodiment of the memory 60 and its contents. The simplified illustration is intended to convey understanding of the general idea of storing different program functions in memory 60, and it is not necessarily a correct technical teaching of the way in which a program would be stored in a real memory circuit. The first memory segment 70 stores program code for controlling the analysis apparatus 14 to perform basic operations. Although the simplified illustration of Figure 3 shows pseudo code, it is to be understood that the program code 80 may be constituted by machine code, or any level program code that can be executed or interpreted by the data processing means 50 (Fig.2).

The second memory segment 90, illustrated in Figure 3, stores a second set of program code 100. The program code in segment 90, when run on the data processing means 50, will cause the analysis apparatus 14 to perform an added function. The added function may include an advanced mathematical processing of a measured signal received via the sensor interface 40. The added function, however, will be enabled and available only if the corresponding key or keyword has been entered.

A keyword embodiment

According to an embodiment of the analysis apparatus 14 (Figure 2), the interface means inlcudes a user input interface 102, whereby an operator may introduce the key in the form of a code word, also referred to as keyword. According to this embodiment the first set of program code 80 in the apparatus 14 inlcudes a program routine for requesting a code word, and for determining whether a received code word is accepted. According to an embodiment the user input interface 102 inlcudes a set of buttons 104. An embodiment of the analysis apparatus 14 inlcudes a user output interface 106. The user output interface may include a display unit 106. The data processing means 50, when it runs a basic program function provided in the basic program code 80, provides for user interaction by means of the user input interface 102 and the display unit 106. The set of buttons 104 may be limited to a few buttons, such as for example five buttons, as illustrated in Figure 2, or nine buttons as illustrated in Figures 7 and 9. A central button 107 may be used for an ENTER or SELECT function, whereas other, more peripheral buttons may be used for moving a cursor on the display 106. In this manner it is to be understood that symbols and text, such as the above mentioned code word, may be entered into the apparatus 14 via the user interface. The display unit 106 may, for example, display a number of symbols, such as the letters of alphabet, while the cursor is movable on the display in response to user input so as to allow the user to input a code word and/or other information. Hence, a key for enabling a disabled condition monitoring

function, and/or for adding an amount of usage allowance to a use restricted condition monitoring function may be entered via the user interface 102, 106 in an advantageously user friendly manner.

The enabled, executable version 110 of the second set of program code 100 may include an analysis routine for processing measured signals or measurement data received on the input 40 from the sensor 10.

According to an embodiment of the invention the second set of program code 100 is disabled by means of encryption. Hence, according to this embodiment the second set of program code 100 is an encrypted set of data 100. The encrypted data 100 is decryptable. Decryption may be achieved by means of a decryption program routine, provided that a correct decryption key, e.g. in the form of a data word, is received. The decryption routine may be comprised in one of the basic functions 80, illustrated in Fig 3.

In the course of decrypting an encrypted set of data 100, the decrypted data 110 may be stored at a third memory location 112.When decrypted, the second set of program code is an executable version 110 of the second set of program code 100. Hence, the memory location 90 may store a disabled version of computer program code and, provided a correct key has been entered, the memory location 112 will provide access to an enabled version of that computer program code.

Although, in the above, enabling of program functions has been described in detail only for a single program function, it to be understood that a large number of analysis functions may be provided in a disabled state in the analysis apparatus 14.

The number of disabled program functions stored by the apparatus 14 may be in the range from one to twenty-five, or even more. This advantageously leads to a wide selection of functions, and the apparatus 14 may be sold at a competitive and

relatively low price in a version where only one or a few of the program functions are enabled. According to a preferred embodiment an enabled program function remains enabled for a limited amount of use such that when the limited amount of use has been consumed, the program function will automatically become disabled again. An additional amount of use of the program function can be added by means of a dedicated usage enabling procedure. Execution of the dedicated usage enabling procedure may require clearance by the distributor. This embodiment of the invention advantageously makes it possible to provide, on the market at a competitively low price, a condition analysis system including a wide variety of program functions so that users may obtain a very versatile instrument at low initial cost. The user may instead pay a certain amount of money for obtaining an additional amount of use of a selected program function.

According to an embodiment of the invention the apparatus 14 stores at least five different disabled program functions, when the apparatus is ready to be delivered to a customer. According to another embodiment the apparatus 14 stores at least fifteen different disabled program functions upon delivery to a customer. According to some embodiments at least two of the initially disabled program functions are, when enabled, for generating indications of the condition of a machine in response to measured vibrations. According to preferred embodiments at least half of the initially disabled program functions are, when enabled, for generating indications of the condition of a machine in response to measured vibrations.

Each one of the disabled functions can be individually enabled in dependence of a key. According to some embodiments of the invention each function is individually enabled dependent on a unique key word. According to an embodiment a group of program functions can be enabled in dependence of one single keyword.

A Mechanical Key Embodiment

According to another embodiment the interface means in the apparatus 14 inlcudes a receptor for receiving a mechanical key (not shown). According to this embodiment an operator may introduce the key in the form of a mechanical key for the purpose of enabling an additional analysis apparatus function. The receptor for receiving a key may include contact means operating to enable the disabled data 100 on reception of the corresponding correct key. According to one version of this embodiment the correct mechanical key may be rotated to cause a contact device to close an electric contact coupled to the memory 60, thereby enabling the reading of a range of memory addresses. Following such a procedure, the data processing means 50 is capable of reading and executing the second set of program code 100 which is stored on the second memory segment 90, i.e. on the range of memory addresses.

A Procedure and a System Providing Tailored Functionality for Evaluating the Condition of a Machine

Analysis of a machine's vibration signature is valuable for reducing unscheduled down time, reducing downtime for repair, minimizing periodic disassembly of a machine for inspection and greatly reducing the probability of catastrophic and unexpected machine failure.

According to one embodiment of the invention, a manufacturer of condition monitoring systems may provide customers with a very versatile, yet non-expensive analysis apparatus 14. The analysis apparatus 14 according to this embodiment allows for "tailored" outfit of Machine Condition Monitoring functions (MCM functions), in accordance with the individual preference of each customer. Potential customers of condition monitoring apparatus range from maintenance personnel - spending all their professional time analysing the condition of machines with the use

of advanced analysis functions - to workshop personnel with a need to make an occasional control of a few machines.

The workshop personnel usually require only a few basic monitoring functions for detection of whether the condition of a machine is normal or abnormal. On detecting an abnormal condition, the workshop personnel may call for professional maintenance personnel to establish the exact nature of the problem, and for performing the necessary maintenance work. The professional maintenance personnel frequently needs and uses a broad range of evaluation functions making it possible to establish the nature of, and/or cause for, an abnormal machine condition. Hence, different users of an analysis apparatus 14 may pose very different demands on the function of the apparatus.

In order to satisfy this broad range of demands, an embodiment of the present condition analysis system advantageously includes an apparatus 14 having a plurality of disabled Machine Condition Monitoring functions, each one of which may be enabled and activated on demand. Such an apparatus 14 for monitoring the condition of a machine can comprise:

at least one input 42 for receiving measurement data from a sensor 10 for surveying a measuring point 12 of the machine; and

data processing means 50 for processing condition data dependent on the measurement data; the data processing means including means for performing at least two condition monitoring functions F1, F2. At least one of the plurality of condition monitoring functions F1, F2 has a locked state and an unlocked state; the locked state prohibiting complete execution of the condition monitoring function; and the unlocked state allowing execution of the condition monitoring function. The apparatus 14 also inlcudes means 141 (Figure 4) for changing the state of a selected condition monitoring function F1, F2 between the locked state and the unlocked state.

This solution advantageously provides the analysis apparatus with an improved versatility. A manufacturer can manufacture the apparatus in a single fashion, and a supplier can sell the apparatus in several versions. More precisely, an apparatus having two individually lockable/unlockable functions can be provided in the following versions:

with only the first function F1 unlocked;

with only the second function F2 unlocked;

with the first function F1 and the second function F2 unlocked.

Hence, a supplier can offer the apparatus in three versions, and this allows for selling it at different price levels dependent on the functionality included. Each client is therefore provided with a choice as to which functions to choose.

The data processing means may include a large number of locked or disabled functions F1, F2, F3... Fn, where n is a positive integer. Each one of the functions F1, F2, F3... Fn may be individually enabled/unlocked or disabled/locked.

Figure 4 is a simplified illustration of a second embodiment of the memory 60 and its contents. As described above, the first memory segment 70 stores program code for controlling the analysis apparatus 14 to perform basic operations.

The second memory segment 90, illustrated in Figure 4, stores a second set of program code 100. The program code in segment 90, when run on the data processing means 50, will cause the analysis apparatus 14 to perform a first Machine Condition Monitoring function (MCM function) F1.

The memory 60 may also include a third memory segment 120, as illustrated in Figure 4, storing a third set of program code 130. The program code in segment 120, when run on the data processing means 50, will cause the analysis apparatus 14 to perform a second Machine Condition Monitoring function F2.

The memory 60 may include a large number of functions F1, F2, F3... Fn, where n is a positive integer. Each one of the functions F1, F2, F3... Fn may be individually enabled/unlocked or disabled/locked as described elsewhere in this document.

Once a function F1, F2, F3... Fn has been enabled it may be individually activated on demand, e.g. by an operator, so that the program function causes the analysis apparatus to perform the tasks prescribed by the computer program function. The functions F1 and F2 have been described in Figure 4 as being stored on separate memory locations, for the purpose of simplifying the understanding of this embodiment of the invention. It is, however, to be understood that the functions F1, F2, F3... Fn may be stored in other manners.

Additionaly, one function Fi, where i is a integer in the range 1..n, may use some, or all, of the program code for another function Fj, where j is an integer in the range 1..n. This means that one function Fi may use another function Fj as a sort of subroutine.

Examples of Machine Condition Monitoring functions

The condition monitoring functions F1, F2...Fn includes functions such as:
vibration analysis, temperature analysis, shock pulse measuring, spectrum analysis of shock pulse measurement data, Fast Fourier Transformation of vibration measurement data, graphical presentation of condition data on a user interface, storage of condition data in a writeable information carrier on the machine, storage of condition data in a writeable information carrier in the apparatus, tachometering, imbalance detection, and misalignment detection.

According to an embodiment the apparatus 14 includes the following functions:
F1 = vibration analysis;
F2= temperature analysis,
F3= shock pulse measuring,

F4= spectrum analysis of shock pulse measurement data,

F5= Fast Fourier Transformation of vibration measurement data,

F6= graphical presentation of condition data on a user interface,

F7= storage of condition data in a writeable information carrier on the machine,

F8= storage of condition data in a writeable information carrier 52 in the apparatus,

F9= tachometering,

F10= imbalance detection, and

F11= misalignment detection.

F12= Retrieval of condition data from a writeable information carrier 58 on the machine.

F13 = Performing vibration analysis function F1 and performing function F12 "Retrieval of condition data from a writeable information carrier 58 on the machine" so as to enable a comparison or trending based on current vibration measurement data and historical vibration measurement data.

F14 = Performing temperature analysis F2; and performing function "Retrieval of condition data from a writeable information carrier 58 on the machine" so as to enable a comparison or trending based on current temperature measurement data and historical temperature measurement data.

F15= Retrieval of identification data from a writeable information carrier 58 on the machine.

Embodiments of the function F7 "storage of condition data in a writeable information carrier on the machine", and F13 vibration analysis and retrieval of condition data is described in more detail in WO 98/01831, the content of which is hereby incorporated by reference.

The vibration analysis function F1 and shock pulse measuring F3 for the evaluation of the condition of a machine may include the step of obtaining a condition value by performing a measurement at the measuring point, such that the condition value is dependent on the actual condition of the machine. According to embodiments, the

routines F1 and F3 may include the step of the microprocessor 50 requesting measured values from the sensor unit 10 (Fig 2). According to one embodiment of the invention the sensor unit inlcudes a transducer having a piezo-electric element. When the measuring point 12 vibrates, the sensor unit 10, or at least a part of it, also vibrates and the transducer then produces an electrical signal of which the frequency and amplitude depend on the mechanical vibration frequency and the vibration amplitude of the measuring point 12, respectively. The electrical signal is delivered to the analog-to-digital converter 44, which with a certain sampling frequency fs converts the analog signal to consecutive digital words in a known way. The microcomputer 50 stores a series of digital words, which correspond to a time sequence of the electrical signal in the memory 60, and then performs an analysis of the signal sequence, whereby the frequency and amplitude of the signal may be determined. Consequently, a measured value for the vibration amplitude Av and the vibration frequency fv may be determined.

According to an embodiment of the above mentioned function F7 "storage of condition data in a writeable information carrier on the machine", one or both of the values vibration amplitude Av and/or vibration frequency fv are delivered to the communications interface 54 (Fig 2). The microcomputer 50, delivers data to the communications interface 54 for the purpose of transmitting such data to the readable and writeable information carrier 58. This may be achieved by means of the communications interfaces 54 and 56, as described above in connection with Figure 2.

The above mentioned function F12 "Retrieval of condition data from a writeable information carrier 58 on the machine" inlcudes: acquiring a value indicating the condition of the machine at an earlier point of time from an information carrier 58 which is placed on, at or in the vicinity of the measuring point 12.

The above mentioned function F13 includes a combination of the above described functions F1 and F12. Hence function F13 includes "Performing vibration analysis" and performing "Retrieval of condition data from a writeable information carrier 58 on the machine" so as to enable a comparison or trending based on current vibration measurement data and historical vibration measurement data. An embodiment of function F13 inlcudes the steps of:

producing an actual condition value, the value being dependent on the actual condition at the measuring point, and

acquiring a stored value, indicating the condition of the machine at an earlier point of time from an information carrier 58 which is placed on the machine 6.

The function F13 may also include presentation of the actual condition value and the stored value on the display 106 for indication of changes. Also, a plurality of stored condition values may be acquired, wherein each condition value is associated with a time and/or date so that trends may be presented on the display.

When the apparatus 14 executes the function F15 "Retrieval of identification data from a writeable information carrier 58 on the machine" it obtains information indicative of the current machine and the current measuring point. Such identification data may be used for storage and retrieval of data in a data base in the memory 52. Such a data base may include stored condition values wherein each condition value is associated with a time and/or date. The retrieved identification data may be used for fetching the relevant previously stored data relating to the current measuring point.

An embodiment of the function F15 "Retrieval of identification data from a writeable information carrier 58 on the machine" may include the data processor 50 retrieving interpretation information relating to the measuring point. The interpretation information may include technical type values such as a diameter value d1 and a rotational speed value V1 relating to a rotating shaft in the machine.

An embodiment of the function F12 "Retrieval of condition data from a writeable information carrier 58 on the machine" also includes retrieving interpretation information relating to the measuring point. With knowledge of the interpretation information d1 and V1,respectively, a measured vibration can be converted to an actual condition value Ka. A predetermined interpretation algorithm is stored in the memory 60, and starting from an amplitude value Av and interpretation information, such as d1 and V1, the micro-computer produces a corresponding condition value Ka dependent thereon. Such an interpretation algorithm is based on an embodiment of a method for producing a condition value described in the Swedish Laid-Open Document 339 576.

According to one embodiment, the interpretation algorithm is based on the machine classification standard ISO 2954.

According to an embodiment of the invention the apparatus 14 includes a function for statically aligning a first shaft with a second shaft. According to an embodiment a function F16 for aligning a first shaft with a second shaft can be performed by connecting a first dual-axis position sensing detector providing a first signal and a second dual-axis position sensing detector providing a second signal to port 16 of the analysis apparatus (Figure 2, Figure 12). When executing the function F16 for aligning shafts, the user interface 106 of apparatus 14 operates to provide readout means having defined alignment conditions and being responsive to the first signal and the second signal for visually displaying shaft alignment, whereby with adjustment of the first shaft with respect to the second shaft, alignment of the first shaft with the second shaft will be indicated on the readout means according to the defined alignment conditions. In order to perform the alignment function an alignment detection device including the first dual-axis position sensing detector for generating the first signal and the second dual-axis position sensing detector for generating the second signal is connected to port 16. The alignment detection device also inlcudes first mount means for mounting the first dual-axis position sensing

detector to the first shaft; second mount means for mounting the second dual-axis position sensing detector to the second shaft; a first alignment radiation source mounted on the first mount means and oriented to provide a first alignment radiation beam to the second dual-axis position sensing detector to generate the second signal; and a second alignment radiation source mounted on the second mount means and oriented to provide a second alignment radiation beam to the first dual-axis position sensing detector to generate the first signal. According to an embodiment of the invention, the apparatus 14, when executing the alignment function in co-operation with the alignment detection device, operates as disclosed in US 4,518,855, the content of which is hereby incorporated by reference.

According to an embodiment of the invention the apparatus 14 also includes a function F17 for balancing a rotating shaft. Also a device to be balanced can be attached to an already balanced shaft of a machine, and thereafter the apparatus 14, when executing the function F17 for balancing, will operate to provide information about the position and weight of the balancing weight(s) needed to counteract an imbalance of the rotating device. The apparatus 14, when executing a version of the function F17 for balancing, will operate to provide information about weight to be removed from the device-to-be-balanced in order to counteract an imbalance and information about the position where that weight needs to be removed. Removal of weight can be achieved, e.g. by drilling.

A Usage Debiting/Crediting Procedure

Figures 5A and 5B illustrate a flow chart illustrating an embodiment of a procedure according to the invention. An operator planning to perform a round of measurements may first consider what type of measurements and analysis is to be done, i.e. what type of Machine Condition Monitoring function is required. The choice of Machine Condition Monitoring function depends on the type of machinery

to be inspected, and on how advanced an evaluation the operator intends to achieve, as described above.

A user help function, provided among the basic functions 80 in the first memory segment 70, can be activated by the operator to provide information about the purpose of any individual function F1 - Fn. This can advantageously contribute to a stepwise increase of the competence of the operator, since the operator may start using relatively simple MCM functions and then, being informed by the user help function, the operator may choose to proceed to using more advanced functions.

Once the operator has decided that he will need to enable a presently disabled function from the group consisting of functions F1-Fn the operator may activate the Usage Debiting/Crediting Routine 132 (Fig. 4). The Usage Debiting/Crediting Routine 132 can also be used for changing the value of a level parameter. The value of the level parameter decides the extent to which the analysis apparatus 14 may be used, as described in further detail below.

The Usage Debiting/Crediting Routine 132 (Fig. 4) is one of the basic functions 80 in the first memory segment 70, which is described in connection with Fig 4 above.

By means of the user interface 102,106 (Figure 2) the operator can activate the Usage Debiting/Crediting Routine, as illustrated by step S110 in Fig.5.

In step S120 (Fig 5), the Usage Debiting/Crediting Routine 132 causes the apparatus 14 to display a list of the available functions, e.g. via the user interface 102/106 (Figure 2). This may include a listing of a plurality of different functions and an indication about status for each individual function. According to a preferred embodiment the status information indicates for each function whether it is disabled or enabled. For the enabled functions the status information may also include information about the remaining amount of use for the associated function. The

remaining amount of use for the associated function is indicated by variables Use_F1 and Use_F2, respectively, for the functions illustrated in Figure 4. As illustrated in Figure 4, there may be a status field 142 associated with each function F1, F2, F3... Fn, the status field 142 including information about whether it is disabled or enabled and, when enabled, information about the remaining amount of use for the associated function. According to this embodiment the level parameter may be a counter value, herein referred to as "Use_F_k", where k is an integer indicating the association with the corresponding function F1, F2, F3... Fn. Hence, function F1is associated with level parameter "Use_F_1", and function F2 is associated with level parameter "Use_F_2" etc.

In step S130 the operator selects to buy more usage of a function. In response thereto a request for an additional amount of usage is generated (S140).

According to an embodiment the request includes information identifying the function whose usage is to be increased, and payment information. The payment information identifies a person responsible for paying the cost of the requested usage or, alternatively the payment information can in itself effect payment. The payment information may include data such as a credit card number. According to another embodiment the payment information may include information indicating that payment has already been effected.

According to an embodiment, the above mentioned request includes information identifying the individual analysis apparatus, and the function whose usage is to be increased, and payment information.

The request is delivered to the premises 28 of a supplier (S150). According to an embodiment the request is delivered by means of the communications network 18 (Fig 1). Hence, request may be delivered from the apparatus 14 to the server computer 20, e.g. via data communication.

At the supplier premises 28 the request is processed (S160), the processing including a verification step for establishing whether the request is to be granted or not. The verification may, for example, include an evaluation of the payment information to decide whether the payment information satisfies certain predetermined payment criteria. According to a preferred embodiment the request is processed automatically by the server computer 20.

According to an embodiment this payment information evaluation includes a step of checking whether the payment information indicates that payment has already been effected, or whether it merely indicates a person responsible for paying the cost. If the payment information merely indicates a person responsible for paying the cost, the server computer 20 may proceed to check with a dedicated database for establishing whether clearance may be given for this person. The dedicated database may include information about the financial situation for the person responsible for paying the cost. According to one embodiment, the server computer limits this clearance check to a verification using data in the database 22 internal to the premises of the supplier 28. According to another embodiment the payment evaluation includes a communication with a financial services database.

Step S170 illustrates that if step S160 results in the request being granted, the supplier will deliver a key to the client (S180). If, on the other hand, the request is not granted, the supplier computer 20 will generate a Request_denied-message. The Request_denied-message may be delivered to a supplier sales person (not shown) for the purpose of alerting the supplier about a failed attempt buy function usage. According to an embodiment, a Request_denied-message is also sent to client part 4 (See figure 1) for causing the apparatus 14 to display information to the effect that the request was denied. The Request_denied-message may include information indicative of the reason for denial of the request, as well as a copy of the original request message, as described in step S140 above.

In step S190 the key is received in the apparatus. The reception of a key may be achieved via the user interface 102,104,106, 182 (See Figures 2, 7, 9, 12 and 15) . Alternatively the key may be received via port 16.

After reception, there is a verification procedure S200 for ascertaining the validity of the key. The result of the verification procedure S200 is an acceptance or a discarding of the key. If the key is not accepted, the apparatus will provide a non-acceptance indication by means of the user interface 106 (Step S210).

If the key is accepted the apparatus 14 will, in response to the key, amend (step S220) a level parameter "Use_F_k"to change an amount of usage status and/or the enabled/disabled parameter 143 for the selected function.

According to an embodiment, the key is associated with the selected function so that, when correctly applied to the apparatus 14, the key will increase the allowed amount of usage of that function. In other words, the key may cause a level parameter associated with the selected function to be amended. The level parameter associated with a selected function is a parameter whose purpose is to indicate how much the apparatus 14 may execute the selected function.

With reference to Fig 4, an embodiment of the invention involving a level parameter is described. According to this embodiment the level parameter may be a counter value, herein referred to as "Use_F_k", where k is an integer indicating the association with the corresponding function F1, F2, F3... Fn. Hence, function F1is associated with level parameter "Use_F_1", and function F2 is associated with level parameter "Use_F_2" etc. According to this embodiment, the key will include a first data portion for associating the key with the corresponding function F1, F2 or F3 etc; and a second data portion for indicating the amount of use purchased.

After execution of step S220, the user interface of the apparatus will present information (step S230) for the purpose of allowing the operator to select a next operation to be executed. This includes selecting between e.g. starting a measurement, returning to step S110 for repeating the above procedure, or turning off the apparatus 14.

Example 1

Figure 5C is a simplified illustration of a principle of an embodiment of an account value or amount of usage parameter for use in an apparatus wherein a user pays to get a number of credits, also referred to as "units of use". It is noted that in the Example 1 embodiment the computer program routine "Function_F1" becomes disabled when the parameter Use_F1 reaches a first reference value (zero in the example).

This example describes an embodiment relating to the above-mentioned procedure. When a client has purchased e.g. ten units of use for the computer program routine "Function_F1" (See Fig. 4), the amount indication portion of the key may cause the parameter Use_F1 to increase by ten units. Hence, if the parameter Use_F1 had a numerical value zero (0) before reception of the key, then the parameter Use_F1 will have numerical value "10" (ten) after correct reception of that key. For each execution of the computer program routine "Function_F1" the numerical value of the parameter Use_F1 will be decreased by one (1). When the computer program routine "Function_F1" has been executed ten times so that the parameter Use_F1 again has the numerical value zero (0), the computer program routine "Function_F1" will become disabled.
In order to enable the computer program routine "Function_F1", the client can purchase a new amount of use by means of the procedure described above.

Example 2

This example describes an embodiment similar to the Example 1 embodiment above. According to example 2, the cost per use changes after a certain level of use has been attained. A user can enter a number Ap of credits or units of use for a selected function, such as function F1, by means of entering a key. When the function F1 is executed by the apparatus 14 the use of the condition monitoring function F1 will be registered by deducting e.g. one credit for each execution. However, the method may also include the steps of:

reading a current value of the registered use;

comparing the current value with a second reference value;

registering use at a first rate when the current value is above the second reference value; and

registering use at a second rate when the current value is below the second reference value.

This advantageously enables a supplier to sell usage at different costs. When, according to one embodiment, a user has paid for a certain amount A_p of usage, the second reference value is a level indicating that the amount A_p of usage already paid for has been spent. This means that any further use will be usage which has not yet been paid for. By the feature of registering such further use at a second rate it is possible to charge a higher cost per unit of usage for such further use. Accordingly, one execution of the function F1, when registered at the second rate, may result in a deduction of two credits.

Figure 5D is an illustration of Example 2. A user, when entering a number Ap of credits or units of use for a selected function, such as function F1, by means of entering a key for the first time, will get Ap credits that will be deducted at the first rate. Assuming that the user has bought ten credits (Ap = 10), the parameter Use_F1 will assume the value 10. Hence, if the first rate is deduction of one credit per execution of function F1, the parameter Use_F1 will assume the value zero ("0")

after ten executions of function F1. When the value zero ("0") is the second reference value, any further execution of the function F1 will be registered at the second rate, e.g two credits per execution. Hence, the user will advantageously still be able to use the function F1, although this use has not yet been paid.

If the first reference value is -4, as illustrated in Figure 5D, the apparatus will allow the function F1 to be executed twice before the parameter Use_F1 assumes the first reference value "minus four" (-4). When the parameter Use_F1 assumes the first reference value, the computer program routine "Function_F1" will become disabled.

However, next time that the user enters a key indicating a value of ten credits, the parameter Use_F1 will assume the value six, since it starts from a negative value:

$$-4 + 10 = 6$$

The above example values of first and second reference values are merely examples. Of course, the number of credits, and the reference values may have other values without departing from the inventive concept described herein. Additionally, the amount of use may be counted as duration of time, the first and second reference values also being indicative of time duration. For example a user may buy allowance to use a selected function for a first total period, e.g. sixty hours, the second reference value being indicative of a time when the charge rate is to be changed, and the first reference value being indicative of a when disabling occurs.

An Embodiment of a Usage Registering Procedure

Figure 6 is a flow chart illustrating an embodiment of a procedure according to the invention.

The procedure may start with step S230, i.e. the user interface of the apparatus presents information for the purpose of allowing the operator to select a next operation to be executed.

In step S240 the operator selects to request the apparatus to perform a Condition analysis function. This means that the operator may select one of the functions whose use is to be registered. The operator may do this by means of the user interface 102,106.

In a step S250 (Figure 6) the computer program 80 (Figure 4) will in response to the operator input check whether the selected operation involves any of the of the functions whose use is to be registered. The functions whose use is to be registered includes the above discussed MCM functions F1 - Fn. A function whose use is to be registered is referred to as a "restricted function" in the following text.

If the selection involves only unrestricted functions the apparatus 14 (Fig2) will initiate and perform such operation (step S260) and then return to step S230.
If a restricted function is selected, the computer program 80 (Figure 4) will in response thereto check whether the selected function is enabled or disabled (Step S270).

If the selected function is disabled, the computer program 80 will present information to this effect (S280), and offer to proceed to any of steps S230, step S110 or S120, described above. According to an embodiment, the program 80 will offer to proceed with step S470 in the procedure described in Figures 14A-14C.

If the selected function is enabled, the computer program 80 will register the use of the selected restricted function (S290), and execute the selected restricted function (Step S300). Although Fig. 6 illustrates a certain order between activities, it to be understood that the invention is not restricted to performing the steps in that

particular order. In particular, the registration of use (step S290) may be performed before or after or sometime during the execution of the restricted function.

According to a preferred embodiment the use is registered by changing the value of a counter parameter Use_F_k. The index k in "Use_F_k" indicates association to function F_k. When the parameter Use_F_k has a value 100, this may indicate that onehundred units of use remains. One unit of use may correspond to one complete execution of the function F_k. Hence, according to an embodiment, the counter parameter Use_F_k can correspond to the number of times the function F_k may be used before all the allowed use has been spent. With reference to Figure 4 step S290 may therefore include amending the parameter Use_Fk in status field 142 for the selected function to update the information indicating the remaining amount of use.

After successful execution and registration of use the computer program 80 may update a status register or status field 142 (step S310). Such update may include updating any and all variables/parameters needed for delivering status information correctly next time step S120 is performed (See Fig 5 and corresponding description). Hence, step S310 may include detection of a usage parameter value Use_F_k indicating that a certain act is to be performed in response to the changed status. For example, if a parameter indicates that all usage for one or all restricted functions has been spent, the the certain act may include disabling the restricted function or functions. Such disabling may include erasing a decrypted version 110, so that only encrypted versions remain.

Figure 7 is a physical embodiment of an apparatus 14. The apparatus has an apparatus body; and a display 106 provided on at least one surface of the apparatus body. Also provided on the body is a user input interface 102 including a key board 103.

The apparatus body is portable; and it is shaped and adapted to enable a one-hand grip, as illustrated in figure 9. **Figure 9** illustrates the apparatus 14 being gripped by a hand 140 of a user. Moreover the user input interface 102 is positioned and adapted so as to enable user interaction by means of the user hand 140. In the embodiment shown in Fig 9 the user input interface 102 is operable by means of a thumb 150 of the user.

Figure 8 is a side view of the apparatus shown in Figure 7. The apparatus body is provided with fasteners 160 for a wrist strap 170. The wrist strap 170 is illustrated in Figure 9.

The body also has a holder 180 for an elongated device. The elongated device may be a pen or a pointing device for user input via the display 106. The display 106 may be a touch sensitive display allowing user input by means of the pointing device. The display 106 therefore includes a display area which is provided with touch sensors 182, also referred to as a touch screen 182, co-operating with a touch input interpreter. Hence, the display may include an LCD unit, for displaying images and text, having integrated touch sensor means for detecting user input via the display area.

The provision of touch sensors 182 for receiving user input via the area of the display 106 provides for an improved user interaction. For example, as described above, the function F13 may include presentation of an actual condition value and a plurality of stored condition values so that trends may be presented on the display 106, wherein each condition value is associated with a time and/or date. When such a trend is displayed, for example in the form of a curve indicating the temporal progression of the condition of the machine, the user may touch the screen at an interesting part of the curve for the purpose of obtaining information associated with that part of the curve. In response to such user interaction the apparatus may

therefore display e.g. the time and date information associated with that part of the curve.

Figure 12 is a block diagram of an embodiment of the apparatus 14 shown in Figure 1 and/or figures 7 and 8. The apparatus according to the Figure 12 embodiment may include a memory 60 having a plurality of program functions F1, F2, F3... Fn, where n is a positive integer. Each one of the functions F1, F2, F3... Fn may be individually enabled/unlocked or disabled/locked.

The memory 60 includes program functions for causing the data processing means 50 to perform the methods described with reference to Figures 5 and 6. Hence, the memory 60 includes a program function 140 (Figure 4) for registering use of any of the functions F1, F2, F3... Fn. The program function 140 may be referred to as a logger, which operates to update the above mentioned use parameters Use_Fk.

Moreover, the memory 60 also includes a program function 141 for changing the state of an individual selected condition monitoring program function between an enabled state and a disabled state. The state control function 141 may operate to read the parameters Use_Fk, as described in connection with step S310 in Figure 6 above. The state control function 141 may operate to disable a function Fk in response to the outcome of a comparison between a parameter Use_Fk and a first reference value Rk. The first reference value Rk is a reference value indicative of a limit. The state control function is adapted to disable function Fk when the parameter Use_Fk reaches the first reference value Rk.

The apparatus 14 includes data processing means 50 in the form of a central processing unit (CPU) 50A co-operating with a Field Programmable Gate Array circuit (FPGA) 50B. According to an embodiment the central processing unit 50A operates to execute the basic functions 80, such as the program functions for causing execution of the methods described with reference to Figures 5 and 6. The Field

Programmable Gate Array circuit 50B is programmable to execute the functions F1, F2, F3... ...Fk... ...Fn. In effect, the CPU 50A, in response to the basic program functions 80 and user input, operates to control the operation of the FPGA 50B. The CPU 50A may, for example, control which of the functions F1, F2, F3... ...Fk... ...Fn are to be executed by the Field Programmable Gate Array circuit 50B.

The Field Programmable Gate Array circuit 50B advantageously provides a combination of flexibility and very high performance to the apparatus 14 in that the functions executed by the FPGA may be software controlled and the FPGA allows for truly parallel processing. Hence, a large amount of data can be processed relatively fast by means of the FPGA. This solution advantageously enables simultaneous execution of two, three or more of the condition monitoring functions F1, F2, F3... ...Fk... ...Fn. The apparatus 14 is highly versatile and flexible in that it can be upgraded to perform new functions simply by adding or changing a program. Hence a new or different condition monitoring function can be added to the apparatus 14 by a simple upgrade of the programs in memory 60 (Figure 2, figure 3, figure 4, figure 12). When the changed program runs on the FPGA the new function can be executed without necessarily changing any of the hardware in the apparatus 14.

Moreover, the FPGA provides a large processing capability in relation to the amount of space it requires. The FPGA may be mounted on a circuit board, where it requires a small surface in relation to the large processing capability it provides. According to an estimate, the amount of surface saved on a circuit board by using an FPGA exceeds 25 %. In other words, the volume of the apparatus 14 can be significantly reduced while the data processing capability is maintained or increased as a result of using an FPGA circuit in the apparatus 14. Therefore the choice of FPGA contributes to enable the provision of a portable instrument satisfying the conflicting requirements of having a large processing capability and a compact instrument which makes it easier to carry for the user.

Additionally the FPGA has a low power consumption as compared to traditional logic circuits as well as when compared to traditional data processors.

The FPGA 50B is coupled to receive digital Shock Pulse Measurement data from an A/D-converter 44A, which is coupled to an input 42A for an analogue Shock Pulse Measurement signal (SPM signal). The FPGA 50B is also coupled to receive digital temperature data from an A/D-converter 44B, which is coupled to an input 42B for an analogue temperature measurement signal. The FPGA 50B is also coupled to receive digital vibration data from an A/D-converter 44C, which is coupled to an input 42C for an analogue vibration measurement signal. Moreover the FPGA 50B is coupled to receive digital data from an A/D-converter 44E, which is coupled to an input 42E for an analogue measurement signal indicative of a measured electric voltage or a measured electric current. The FPGA 50B is also coupled to an input 42D for receiving binary tachometering measurement signals.

The FPGA 50B is also coupled to a communications interface 54 for bi-directional communication with a device 59 on a machine 6, as described in connection with Figure 2.

Moreover the apparatus 14 includes a user interface 102. The user interface 102 includes a display 106 having touch sensors 182 for associating information displayed at a certain position of the display area with user activation of the sensor at the certain position. In the block diagram of Figure 12 the touch sensor 182 is illustrated as a block separated from the display 106. In a physical embodiment, however, the touch sensors 182 are integrated with the display area 106, as illustrated in Figure 7, such that the touch sensors 182 detect user interaction with the display area 106.

The CPU 50A is coupled to a data port 16 as described in connection with Figure 1, for enabling communication with a supplier computer 20.

The apparatus 14 also includes clock functionality 210 for providing time and date information. This is useful for generating a time stamp, e.g. when a condition value has been produced, and the value is to be stored for future retrieval. Additionally, the time and date information may be used for controlling the enabling and disabling of functions F1, F2, F3... ...Fk... ...Fn. According to an embodiment, the apparatus 14 may receive, via port 16, a key including a code for enabling a selected function from a first predetermined date, such as e.g March 1, 2003, until a second date such as April 15 2003. Such a key may include a data portion indicative of the identity of the analysis apparatus, a data portion indicative of the function to be enabled, a data portion indicative of the first date and a code portion indicative of the second date.

Alternatively the key may cause a selected function to be enabled for a certain duration starting from a certain date.

According to an embodiment the apparatus inlcudes a logger operating to register the amount of use for one, some or all condition monitoring functions, as described above. This may be done by counting the number of executions of the restricted functions, as described above. According to an embodiment a Reporting function is provided, among the Basic Program Functions 80 (Fig. 3 & 4), for causing the apparatus 14 to deliver a report about the accumulated registered use. The reporting function is adapted to deliver such a report with a certain periodicity. For example, the Reporting function may be set to deliver a report no less than once every 30 days. The reporting function is set to deliver the report via the port 16 for transmission to the supplier computer 20 via the communications network 18 (Fig 1). Upon reception of the report, the supplier computer may be adapted to cause an output to the supplier indicative of the amount of use accumulated for that particular analysis

apparatus. Alternatively the supplier computer may be arranged to automatically generate an invoice with a certain regularity, such as no less than once every 30 days, the invoice thereafter being delivered to a user associated to the analysis apparatus. For this purpose the usage report may include data indicative the identity of the user. This may be achieved by providing unique identities for each analysis apparatus, and keeping, at the supplier, a data base 22 associating each unique analysis apparatus identity with a corresponding client/user. The reporting function co-operates with the timer functionality 210 such that if no usage report has been transmitted at the expiration of the certain period, the timer co-operates with the State control function 141 to disable one, several or all the restricted functions F1, F2, F3... ...Fk... ...Fn. According to another embodiment the apparatus 14 expects to receive a receipt from the supplier part 20, 28 after sending a usage report. The receipt should include information, preferably in a coded manner, indicating that the usage report has been received by the supplier part 20, 28. If no receipt has been received within a first time period the apparatus will provide a warning to the user by means of the user inteface106. If no receipt has been received within a longer, second time period the apparatus will disable one, several or all the restricted functions F1, F2, F3... ...Fk... ...Fn.

Fig. 15 shows a schematic block diagram of another embodiment of a condition analyzing system 2. According to the Figure 15 embodiment the client part 4 inlcudes an apparatus 14, and a separate client computer 300. The client computer 300 may be connectable to a communications network 18, e.g. via a data interface19. The communications network 18 may be the world wide internet, also known as the Internet. The communications network 18 may also include a public switched telephone network. The supplier part may be able to exchange information with the computer 300 via the communications network 18, e.g. in the manners discussed above in connection with Figure 1.

According to an embodiment the apparatus 14 is connectable to the computer 300 via port 16, for exchanging information relating to usage. According to a preferred embodiment the apparatus 14 delivers the above mentioned usage report to the supplier via the computer 300. According to an embodiment information exchange between the apparatus 14 and the computer 300 may be achieved by transfer of a writeable memory device connectable to the computer 300 as well as to the apparatus 14. Information exchanged in this manner may include the above mentioned usage report, and/or the above mentioned receipt indicating to the apparatus 14 that the usage report has been received by the supplier part 20, 28. The coded information in the receipt may also be read by a user from the user interface of computer 300, and input into the apparatus 14 by means of user interface 106, 182, 103.

Figure 13A illustrates a part of memory 60 including a function F_k and an associated status field 142. The status field 142 includes a segment 143 for data indicative of the state of the associated function: enabled or disabled. The status field 142 also includes a segment 144 having data indicative of the cost C_{fk} for executing the associated function Fk. For example, function F1 may have a cost value $C_{fk}= 1$ charging unit per execution, and function F3 may have a cost value $C_{fk}= 3$ charging units per execution. In another example, function F1 may have a cost value $C_{fk}= 1$ charging unit per unit of time, whereas function F3 may have a cost value $C_{fk}= 3$ charging units per unit of time. Hence, different functions may be charged at different cost rates, by providing a certain exchange rate between one charging unit and a certain monetary currency. For example one charging unit may correspond to x US cents, where x is a number such as 10, 15, 50, 100, 1000 or another number dependent on what price is suitable.

An alternative embodiment for registering use, i.e. an embodiment of step S290 in Figure 6, is as follows: The use maybe registered by counting a duration of execution of a restricted function, in which case the registration of use may include a

performed immediately before the execution of the restricted function, and the step S290B is executed immediately thereafter. According to this embodiment the parameter Use_F_k may be indicative of a total duration of time the function F_k has been activated. **Figure 13B** illustrates a part of memory 60 according to this embodiment, including a function F_k and an associated status field 142_k. The parameter Use_F_k, indicative of an accumulated total duration of active time for the function F_k, is stored by the logger in a segment 220_k in status field 142_k. A reference duration value is stored in segment 230_k, and a cost factor may be stored in a segment 240_k. The reference duration value is set by reception of a key, and it indicates an amount of use that has been paid for. According to this embodiment the state control function may be arranged to disable Function F_k when the parameter Use_F_k in segment 220 is equal to the reference duration value in segment 230_k. Different charges per time unit for different functions F_k, F_i may be obtained by a multiplying the duration of execution of a restricted function F_k with a cost factor C_k, and multiplying the duration of execution of another restricted function F_i with a different cost factor C_i. The cost factors for functions F_k and F_i, respectively, may be stored in a memory segments 240_k and 240_i respectively. In accordance with the same principle, different charges per execution for different functions F_k, F_i may be obtained by a multiplying the number of executions of a restricted function F_k with a cost factor C_k, and multiplying the number of executions of another restricted function F_i with a different cost factor C_i. In this manner the mutually different functions F_k, F_i can be charged at different costs per execution.

Another Embodiment of a Usage Debiting/Crediting Procedure

This embodiment differs from the Usage Debiting/Crediting Procedure described with relation to Figure 5 in that there is provided a centralized debit/credit account parameter 250 rather than separate accounts for each function. There is a plurality of restricted functions having individually settable states: either disabled or enabled.

The enabling/disabling procedure is a separate procedure being performed in response to a state key associated with the selected function. There is a separate credit/debit key for allowing a supplier to amend the value of the centralized debit/credit account parameter 250.

According to this embodiment the request includes information identifying the individual analysis apparatus, and payment information. The key to be received may cause a level parameter associated with the use of all relevant functions in that individual analysis apparatus to be amended. Hence, such a level parameter may be associated with all MCM functions.

Whenever a client operator selects to use a restricted function, the amount of use is deducted from centralized debit/credit account 250. Only those functions which are in the enabled state can be activated for execution, provided the centralized debit/credit account parameter 250 has a value above a first reference value. The first reference value is a limit value, such that if an operator attempts to execute a restricted function when the value of the centralized debit/credit account parameter 250 is equal to, or exceeds the first reference value, then the registering routine causes the apparatus 14 to disable all restricted functions.

One version of this embodiment further inlcudes the steps of:

reading a current value of the centralized debit/credit account parameter 250;

comparing the current value with a second reference value;

deducting credit units from the centralized debit/credit account parameter 250 at a first rate when the current value is above the second reference value; and

deducting credit units from the centralized debit/credit account parameter 250 at a second rate when the current value is below the second reference value.

This advantageously enables a supplier to sell usage at different costs. When, according to one embodiment, a user has paid for a certain amount A_p of usage, the second reference value is a level indicating that the whole amount A_p of prepaid usage has been spent. This means that any further use will be usage which has not yet been paid for. By the feature of registering such further use at a second rate it is possible to charge a higher cost per unit of usage for such further use.

Moreover, the amount of use may be charged at different rates for different functions by means of individual cost factors (C_k and C_i, respectively) associated with each individual function, as described above and as illustrated in Figures 13A and 13B.

The centralized debit/credit account parameter 250 may be stored in a memory location 260 in the memory 60, as illustrated in Figure 4.

Figure 14 is a flow chart illustrating an embodiment of a procedure for delivering an apparatus 14, and for adding use or functionality by means of a key from the supplier part 28. The method also relates to an embodiment of a method for generating a request for such a key or code. Such a key/code may be used for amending the centralized debit/credit account parameter 250 and/or for enabling a disabled function. Step S610 in Figure 14C may include the procedure according to Figure 6, starting e.g. with step S230. It is to be understood that Figure 14 focuses on certain mathematical or technical details that may also be used in the context of the procedure described in connection with Figure 5A and 5B above. The method may start at the supplier 28 (Figure 1, Figure 15) before delivery of the apparatus. In a step S410 a code ki is set to a start value, which may be chosen to e.g. 0. Thereafter identity information is entered. This may be a number identifying an individual apparatus 14, or information identifying an individual condition monitoring function or both. A new code K_{i+1} is generated in accordance with a first mathematical algorithm in dependence of the identity information and the previous code k_i (S430).

The variable K_i is updated to the value of the new code K_{i+1} (step S440). The updated value K_i is stored in the apparatus 14, and in the supplier database 22 (step S450). The copy stored in supplier database 22 is herein referred to as K_{i22}, and the copy stored in the apparatus 14 is herein referred to as K_{i14}.

The apparatus is delivered to a client/user (step S460). Thereafter the user may operate the apparatus as described in connection with Figures 5A,5B and/or Figure 6.

At some point in time the user may want to buy additional use allowance. The user may then cause the apparatus to generate a request U_R (Use Request) for additional Use allowance (step S470). Step S470 may be attained as described in connection with steps S130, S140 in Figure 5A. The request U_R is received in supplier computer 20 (step S480). In supplier computer 20 the code K_{i22} is retrieved from database 22. The code K_{i22} and the content of the request U_R are used in a predetermined mathematical algorithm, and a checksum S_{c1} with a certain number of bits is produced. Hence checksum S_{c1} is generated in response to code K_{i22} and the content of the request U_R (step S500).

A new code K_{i+1_22} is generated in response to the old code K_{i22} and identity information(step S510). This may be done in a manner analogous to step S430.

In step S520 the new code value K_{i+1_22} is stored in database 22 as updated code new code K_{i22}.

A key including the information in the request U_R and the checksum Sc1 is delivered from the supplier (step S530). This may be achieved as discussed elsewhere in this document, e.g. as discussed in connection with Figure 5A.

The key, including the information U_R and Sc1 is received in apparatus 14(step S540). This may be achieved as discussed elsewhere in this document, e.g. as

discussed in connection with Figure 5A (S190). A key verification procedure is performed, as discussed in connection with connection with Figure 5A (S200). The key verification procedure includes calculating a checksum. In apparatus 14 the code K_{i14} is retrieved from memory. The code K_{i14} and the content of the request U_R are used in the above in step S500 mentioned predetermined mathematical algorithm, and a checksum S_{c2} with a certain number of bits is produced. Hence checksum S_{c2} is generated in response to code K_{i14} and the content of the request U_R (step S550).

In a subsequent step S560, the generated checksum S_{c2} is compared to the received checksum S_{c1} (step S560 and step S570). If they are not identical an error message is displayed, as discussed in connection with S210 above in connection with Figure 5B.

If they are identical then this means that the key is accepted, and the apparatus 14 proceeds to add the use allowance in apparatus 14 (step S600). Thereafter the user may use the apparatus, as discussed in Figure 6 (step S610).

When additional usage allowance is desired the user may again request additional use, by following the above described procedure, starting with step S 470 as illustrated in Figure 14A, 14B, & 14C and as described above.

Figure 10 is a top view of an embodiment of the apparatus 14, illustrating the physical dimensions thereof. **Figure 11** is a side view of the apparatus shown in Figure 10.

The display 106 has an extension xd in a first direction and an extension Yd in a orthogonal direction such that the display area is at least 4125 mm^2.

The apparatus body has a first portion 190 adapted for gripping by a user. The first portion has an extension x1 in a first direction, an extension y1 in a second direction. The body has an extension z1 in a third direction, as illustrated in Figure 11. The

body also has a second body portion 200 having an extension x2 in a first direction, and an extension y2 in a second direction. The second portion inlcudes at least a part of the display 106.

According to an embodiment:

x1 is less than 80 mm

y1 is less than 140mm

z1 is less than 35 mm

x2 is less than 100 mm

y2 is less than 160 mm

xd is at least 60 mm

yd is at least 80 mm

This embodiment provides an apparatus 14 having a body volume of less than 952 000 mm^3, and the display 106 has a display area of at least 4800 mm^2. Therefore the apparatus 14 is easily portable in a handheld manner, whereas the user interface is advantageously user friendly by means of a large display in relation to the body volume of the apparatus.

According to another embodiment :

x1 is less than 65 mm

y1 is less than 145mm

z1 is less than 35 mm

x2 is less than 80 mm

y2 is less than 145 mm

xd is at least 60 mm

yd is at least 80 mm

This embodiment provides an apparatus 14 having a body volume of less than 735 875 mm^3, and the display 106 has a display area of at least 4800 mm^2. This

embodiment of the apparatus 14 is even easier to carry in in a handheld manner, while providing a large display in relation to the body volume of the apparatus.

According to yet another embodiment :

$x1$ is less than 60 mm

$y1$ is less than 120mm

$z1$ is less than 30 mm

$x2$ is less than 80 mm

$y2$ is less than 140 mm

xd is at least 60 mm

yd is at least 80 mm

This embodiment provides an apparatus 14 having a body volume of less than 552 000 mm^3, and the display 106 has a display area of at least 4800 mm^2.

According to another embodiment the apparatus 14 has a body volume of less than 1006 250 mm^2, and the display has a display area of at least 4800 mm^2. According to another embodiment the apparatus 14 has a body volume of less than 800 000 mm^2.